AD-A069 553 FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OH F/G 8/10

MEASURING LOCALLY ISOTROPIC HYDROPHYSICAL FIELDS,(U)

DEC 78 S V DOTSENKO

UNCLASSIFIED FTD-ID(RS)T-1897-78 NL

1 OF 1

AD A069553

END

DATE FILMED

7--79

DDC

FTD-ID(RS)T-1897-78

AD-A069553

FOREIGN TECHNOLOGY DIVISION

MEASURING LOCALLY ISOTROPIC HYDROPHYSICAL FIELDS

by

S.V. Dotsenko

Approved for public release;
distribution unlimited.

79 04 26 182

EDITED TRANSLATION

FTD-ID(RS)T-1897-78   6 December 1978

MICROFICHE NR: FTD-78-C-001678

MEASURING LOCALLY ISOTROPIC HYDROPHYSICAL FIELDS

By: S.V. Dotsenko

English pages: 10

Source: Morskiye Gidrofizicheskiye Issledovaniya
No. 3(53), 1971, pp. 83-90

Country of orogin: USSR
Translated by: Sgt. Martin Folan
Requester: FTD/SDSY

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.	PREPARED BY: TRANSLATION DIVISION FOREIGN TECHNOLOGY DIVISION WP-AFB, OHIO.

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

MEASURING LOCALLY ISOTROPIC HYDROPHYSICAL FIELDS

S. V. Dotsenko

Abstract

We have found a tie between the spectrum of an output signal of an instrument with the spectrum of a locally isotropic field measured by it, the knowledge of which permits correcting the spectrum's distortion introduced by the instrument. The acquired results illustrate, for example, corrections of the spectrum of fluctuations in transmittance of sea water.

One of the methods of studying the physical processes which occur in the ocean is the study of the physical fields created by it such as the flow velocity, temperature, salinity, transmittance, speed of sound, etc. [1]. The methods of measuriing these fields can be varied: vertical sounding at a ship's anchorage, measuring the fields with instruments (on the horizons of buoy stations or on self-reacting floating devices), or measuring the ship's path with operating (towed) instruments. The various methods of measurement correspond to the solution of various oceanographic prob-

lems.

With vertical sounding, as a rule, we solve the problem of investigating the distribution of determined components of a field with respect to depth. With horizontal movement of the instrument, we usually study the statistical characteristics of the measured field at a given depth, where a change in the determined component of the field is comparatively small.

Let us pause in more detail on measuring the statistical characteristics of the studied scalar field with towing of the measuring instrument.

It was recently shown that the physical fields of the ocean are subjected to time and spatial fluctuations with extremely large spectra of frequencies, which change from fractions of a second to a year and more, and from a centimeter to scales of the entire ocean in general. It is apparent that it is not possible to construct a method of measuring these fields, to an equal degree suitable for studying in any ranges of the indicated spectra. The towed instruments are built for studying nonuniformities, the scales of which lie within the limits of centimeters to tens of meters, and therefore the basic requirement for it is the best representation of the features which are inherent to the measured fields within the limits of precisely these scales. Since we are speaking of the statistical characteristics of fields, then the problem of the theory of measuring can be formulated here in the following manner: as with respect to the data of measurements acquired with the aid of the towed measuring device, to restore the statistical characteristics of the measured field. Let us note

that the statistical characteristics of the output signal of the instrument and of the studied field do not coincide, since the instrument possesses properties of spatial averaging and inertia which distort the form of these characteristics.

Let us study the tie between the statistical characteristics of the output signal of the towed instrument and the statistical characteristics of the studied field in the supposition that the latter is locally isotropic (this requirement is satisfied by a wide class of physical fields encountered in the ocean), and the measurement lasts for a rather long time. Here, we will consider the condition of "frozen turbulence" of Taylor for the studied field as accomplished.

The random tridimensional field $X(\vec{\rho})$, where $\vec{\rho}$ - radius-vector of the field's points, is called locally uniform, if all distributions of probabilities for differences of its values in combination of pairs of points do not change with any parallel transfer of all the examined points [2]. The average value of increments $\Delta_{\vec{r}} X(\vec{\rho}) = X(\vec{\rho}+\vec{r}) - X(\vec{\rho})$ of this field is linear function of vector $\vec{r}$:

$$m(\vec{r}) = \overline{\left[X(\vec{\rho}+\vec{r}) - X(\vec{\rho})\right]} = \vec{c}_1 \vec{r},$$

where $\vec{c}_1$ - constant vector, the total second moment of increments $\Delta_{\vec{r}} X(\vec{\rho})$ of field $X(\vec{\rho})$

$$D(\vec{\rho}_2 - \vec{\rho}_1, \vec{r}_1, \vec{r}_2) = \overline{\left[X(\vec{\rho}_1+\vec{r}_1) - X(\vec{\rho}_1)\right]\left[X(\vec{\rho}_2+\vec{r}_2) - X(\vec{\rho}_2)\right]} \qquad (1)$$

is reflected by the structural function of this field

$$D(\vec{r}) = \overline{\left[X(\vec{\rho}+\vec{r}) - X(\vec{\rho})\right]^2}$$

with the aid of equation

$$D(\vec{\rho}, \vec{r}_1, \vec{r}_2) = \frac{1}{2}\left[D(\vec{\rho}-\vec{r}_1) + D(\vec{\rho}+\vec{r}_2) - D(\vec{\rho}-\vec{r}_1+\vec{r}_2) - D(\vec{\rho})\right].$$

The structural function is simply determined by its spectral density (tridimensional spectrum) $G(\vec{\alpha})$:

$$D(\vec{r}) = 2\int(1-\cos\vec{\alpha}\vec{r})\,G(\vec{\alpha})\,d\vec{\alpha}. \qquad (2)$$

The locally uniform field, depending only on $r = |\vec{r}|$, is called locally isotropic. The tridimensional spectrum of this field can be expressed through its uniform spectrum $G_1(\alpha)$ with the aid of relationship

$$G(\alpha) = -\frac{1}{2\pi\alpha}\,\frac{dG_1(\alpha)}{d\alpha}. \qquad (3)$$

If field $Y(t)$ is uniform, then it carries the name of a random process with stationary transfers. Its average value is

$$m_Y(t_1) = \overline{[Y(t+t_1) - Y(t)]} = d_1 t_1, \qquad (4)$$

where d_1 - constant, and the structural function

$$D_Y(t_1) = \overline{[Y(t+t_1) - Y(t)]^2} \qquad (5)$$

is connected with its spectrum in the following manner:

$$D_Y(t_1) = 2\int_{-\infty}^{\infty}(1-\cos\omega t_1)\cdot S(\omega)\,d\omega. \qquad (6)$$

The tie between the output signal of the instrument $Y(t)$ towed with respect to the studied medium with constant velocity $\vec{V}_0$, with the measured field $X(\vec{\rho})$ has the form [3]

$$Y(t) = \int d\vec{\rho}\int_{-\infty}^{\infty} X[\vec{V}_0(t-\tau) - \vec{\rho}]\,H(\vec{\rho};\tau)\,d\tau, \qquad (7)$$

where $H(\vec{\rho};\tau)$ - the spread function of the instrument, characterizing the properties of spatial averaging and inertia which are

inherent to it. Thus, in accordance with expression (7), the instrument conducts a transformation of the studied tridimensional field to an output uniform signal. We show that with towing of the instrument with a constant velocity in the locally isotropic field its output signal represents a random process with stationary increments, and we will find the tie of the spectrum of this process with the spectrum of the field.

Placing expression (7) in relationship (4), we obtain the average value of output signal $m_Y(t_1) = \bar{c}_1 \vec{v}_0 t_1$, which linearly depends on t_1, which is typical for a random process with stationary increments.

Let us find the structural function of output signal of the instrument. Placing expression (7) in formula (5), we obtain

$$D_Y(t_1)=\int d\vec{\rho}\int d\vec{\rho}'\int_{-\infty}^{\infty} d\tau\int_{-\infty}^{\infty} D\left[\vec{v}_0(\tau-\tau')+(\vec{\rho}-\vec{\rho}'),\vec{v}_0 t_1,\vec{v}_0 t_1\right] H(\vec{\rho};\tau) H(\vec{\rho}';\tau')\, d\tau', \qquad (8)$$

in which regard the total second moment of the field which is located under the integral is determined with the aid of relationship (1) and can be represented through the structural function of the field in the form

$$\frac{1}{2}\left\{D\left[\vec{v}_0(\tau-\tau'-t_1)+(\vec{\rho}-\vec{\rho}')\right]+D\left[\vec{v}_0(\tau-\tau'-t_1)+(\vec{\rho}-\vec{\rho}')\right]-\right.$$
$$\left.-2D\left[\vec{v}_0(\tau-\tau')+(\vec{\rho}-\vec{\rho}')\right]\right\}.$$

With the aid of relationship (2) after uncomplicated transformations, we reduce relationship (8) to form

$$D_Y(t_1)=2\int\left[1-\cos(\vec{\varkappa}\vec{v}_0 t_1)\right]\cdot H(\vec{\varkappa};\vec{\varkappa}\vec{v}_0)\, \Phi(\vec{\varkappa})\, d\vec{\varkappa},$$

where $H(\vec{\varkappa}:\omega)=\left|\tilde{H}(\vec{\varkappa};\omega)\right|^2$ is the energy spectral characteristic of the instrument, in which regard $\tilde{H}(\vec{\varkappa},\omega)$ represents a four-dimensional

spectrum of the spread function of the instrument

$$\widetilde{H}(\vec{\alpha};\omega)=\int d\vec{\beta}\int_{-\infty}^{\infty} H(\vec{\beta};\tau)\, e^{-j(\vec{\alpha}\vec{\beta}+\omega\tau)}\, d\tau.$$

Let us take the system of coordinates $(\vec{\iota}_0, \vec{j}_0, \vec{\kappa}_0)$ relative to which the instrument moves in such a manner that the velocity vector of towing $\vec{V}_0$ coincides with the coordinate axis $\vec{\iota}_0$ with respect to direction. Here

$$D_Y(t_1)=2\int\left[1-\cos(\alpha_1 v_0 t_1)\right] H(\alpha_1,\alpha_2,\alpha_3;\alpha_1 v_0)\, G(\alpha_1,\alpha_2,\alpha_3)\, d\alpha_1\, d\alpha_2\, d\alpha_3.$$

Replacing in the obtained equation $\alpha_1 v_0=\omega$, we find that the structural function of the output signal of the instrument has the form (6) (i.e. the output signal is actually a random process with stationary increments),in which regard the spectrum of the output signal $S(\omega)$ is connected with the spectrum of field by relationship

$$S(\omega)=\frac{1}{V_0}\int H\left(\frac{\omega}{V_0},\alpha_2,\alpha_3;\omega\right) G\left(\frac{\omega}{V_0},\alpha_2,\alpha_3\right) d\alpha_2\, d\alpha_3. \tag{9}$$

For a number of hydrophysical instruments, consisting of noninertia sensor and an inertial measuring part, condition of separating the energy spectral characteristics is accomplished

$$H(\vec{\alpha};\omega)=H_\alpha(\vec{\alpha})\, H_\omega(\omega).$$

With the fulfillment of this condition and local isotropy of the field, expression (9) assumes the form

$$S(\omega)=H_\omega(\omega)\, S_0(\omega), \tag{10}$$

where the spectrum at the output of the noninertia sensor

$$S_0(\omega)=\frac{1}{V_0}\int H_\alpha\left(\frac{\omega}{V_0},\alpha_2,\alpha_3\right) G\left[\sqrt{\left(\frac{\omega}{V_0}\right)^2+\alpha_2^2+\alpha_3^2}\right] d\alpha_2\, d\alpha_3. \tag{11}$$

Relationship (10) represents the well-known expression of transformation of the energy spectrum of a uniform signal with the passing of it through the linear target.

Let us examine the detailed expression (11). Let us express the signal spectrum at the output of sensor (11) through the uniform spectrum of the field, using relationship (8). After the transformation we obtain

$$V_0 S_g(\omega) = M_\alpha\left(\frac{\omega}{V_0}, 0, 0\right) G_1\left(\frac{\omega}{V_0}\right) - \int_0^\infty F\left(\frac{\omega}{V_0}, x\right) G_1\left[\frac{1}{a}\sqrt{\left(\frac{\omega a}{V_0}\right)^2 + x^2}\right] dx, \qquad (12)$$

where a - some typical dimension ofthe sensor, and function

$$F\left(\frac{\omega}{V_0}, x\right) = -\frac{1}{2\pi}\frac{\partial}{\partial x}\int_0^{2\pi} M_\alpha\left(\frac{\omega}{V_0}, \frac{x}{a}\cos\varphi, \frac{x}{a}\sin\varphi\right) d\varphi$$

will be called the function of transverse averaging. It depends on the degree of averaging of the field by the sensor in a plane which is perpendicular to the direction of movement, and equal to null, if this averaging is absent. Thus, this function depends on the cross section of the sensor in a direction perpendicular to the speed of movement and also means that it depends on the orientation of the sensor.

According to formula (12), generally the spectrum of a signal at the output of the sensor does not lead to the production of a uniform spectrum of the measured field by an energy spectral characteristic of the sensor, and represents a complex transformation of the field's spectrum. This transformation leads to a suppression of the high-frequency components of the spectrum.

For finding $G_1(\alpha)$ according to the known $S_g(\omega)$ and $F\left(\frac{\omega}{V_0}, x\right)$ it is necessary to solve integrated equation (12). Analytical methods of solving it are complex and, apparently, inexpedient, since the spectrum at the output of sensor $S_g(\omega)$, as a rule, is found in the course of treating the realization of measurement on a computer in a discrete amount of points and is represented in the form of

a table of numbers. Therefore, the more natural here proves to be numerical methods, which, for the given instrument, can be immediately incorporated in the program of computing the field spectrum on a computer. One of the simplest and most perspective is the method of simple iterations [4], consisting of the fact that the n -approximation of the field spectrum $G_{1(n)}\left(\frac{\omega}{V_0}\right)$ is expressed through $(n-1)$- $G_{1(n-1)}\left(\frac{\omega}{V_0}\right)$, according to relationship (12) , in the form

$$G^{\cdot}_{1(n)}\left(\frac{\omega}{V_0}\right) = \frac{1}{\dot{M}_{\alpha}\left(\frac{\omega}{V_0}, 0, 0\right)} \left\{ V_0 S_g(\omega) + \int_0^{\infty} F\left(\frac{\omega}{V_0}, x\right) G_{1(n-1)}\left[\frac{1}{a}\sqrt{\left(\frac{\omega a}{V_0}\right)^2 + x^2}\right] dx \right\}, \quad (13)$$

in which regard, as the null approximation, it is natural to take value $\frac{V_0 S_g(\omega)}{M_{\alpha}\left(\frac{\omega}{V_0}, 0, 0\right)}$. The first approximation doubles the range in which the spectrum obtained in the result of processing, can be computed in coincidence with the field spectrum. Repeating operation (13) many times, we can, in the region where $M_{\alpha}\left(\frac{\omega}{V_0}, 0, 0\right) \neq 0$, obtain a solution to equation (12) with any previously assigned accuracy. This affords the possibility of obtaining a field spectrum in a pure form, excluding the influence of spectral characteristic of the measuring instrument.

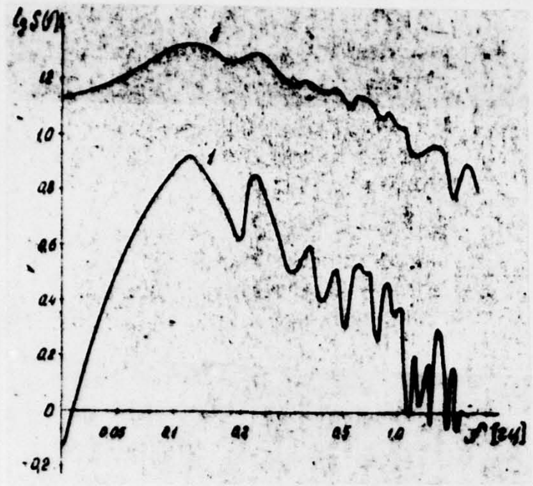
Let us illustrate what has been proposed above on the example of a signal spectrum at the output of a measurer of optical transmittance of sea water, which was obtained in the Atlantic Ocean by the scientific research ship "Mikhail Lomonosov" on its 21st cruise (curve 1 in the figure) [5]. The base of the instrument has length $a = 66$ см , speed of movement $v_0 = 45$ cm/sec, and the base of the instrument is oriented perpendicular to the direction of movement. The frequency characteristic of the inertial part of the instrument

has a pass band which is wider than 10 Hz, which gives the ability to consider the instrument in a range of frequencies fro 0-2.5 Hz noninertial. The signal spectrum at the output of this instrument sharply decreases with frequency.

The solution to equation (12) for this case gives a field spectrum reflected by curve 2, the degree of decrease of which is substantially smaller than for the signal spectrum. As we can see from a comparison of these spectra, the transmittance measurer's sensor weakens the high frequencies, which can lead to an error interpretation of the results of measurements. A calculation of the drift and properties of spatial averaging of the instrument permits avoiding these errors.

A sharp difference in the spectrum of an output signal and a field spectrum is caused by the fact that, in the given case, we are studying the spectrum of spatial nonuniformities of the field, the scales of which are comparable to the dimension of the sensor of the instrument. Here, the sensor represents a spatial filter, separating the higher frequencies. If with the measurement we set the purpose of investigating the spectra of nonuniformities, the scales of which substantially (by 5 or more times) exceed the dimensions of the sensor, then the spectrum of the output signal practically coincides with the field spectrum, and there is no necessity for these computations.

Figure. Spectrum of a signal at the output of a transmittance measurer (1) and the spectrum of a field of transmittance (2).



BIBLIOGRAPHY

1. Колесников А.Г. Автоматизированная система сбора, передачи и обработки информации о физических полях океана. – В кн.: Автоматизация научных исследований морей и океанов. Севастополь, изд. МГИ АН УССР, 1968.
2. Монин А.С., Яглом А.М. Статистическая гидромеханика. Ч. 2. М., "Наука", 1967.
3. Шестов Н.С. Выделение оптических сигналов на фоне случайных помех. М., "Сов. радио", 1967.
4. Михлин С.Г., Смолицкий Х.Л. Приближенные методы решения дифференциальных и интегральных уравнений. М., "Наука", 1965.
5. Харченко А.С., Неуймин Г.Г. Исследование неоднородности прозрачности воды в океане. – В кн. Исследования междуведомственной экспедиции в Северо-Западной Атлантике. Севастополь, изд. МГИ АН УССР, 19[illegible]

DISTRIBUTION LIST

DISTRIBUTION DIRECT TO RECIPIENT

ORGANIZATION		MICROFICHE
A205	DMATC	1
A210	DMAAC	2
B344	DIA/RDS-3C	9
C043	USAMIIA	1
C509	BALLISTIC RES LABS	1
C510	AIR MOBILITY R&D LAB/FIO	1
C513	PICATINNY ARSENAL	1
C535	AVIATION SYS COMD	1
C591	FSTC	5
C619	MIA REDSTONE	1
D008	NISC	1
H300	USAICE (USAREUR)	1
P005	DOE	1
P050	CIA/CRB/ADD/SD	1
NAVORDSTA (50L)		1
NASA/KSI		1
AFIT/LD		1
LLL/Code L-389		1

ORGANIZATION		MICROFICHE
E053	AF/INAKA	1
E017	AF/RDXTR-W	1
E403	AFSC/INA	1
E404	AEDC	1
E408	AFWL	1
E410	ADTC	1
	FTD	
	CCN	1
	ASD/FTD/NIIS	3
	NIA/PHS	1
	NIIS	2